Scaling of the microwave magneto-impedance in $Tl_2Ba_2CaCu_2O_{8+\delta}$ thin films.

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Abstract

We present measurements of the magnetic field-induced microwave complex resistivity changes at 47 GHz in $Tl_2Ba_2CaCu_2O_{8+\delta}$ (TBCCO) thin films, in the ranges 58 K< $T < T_c$ and 0< $\mu_0 H$ <0.8 T. The large imaginary part $\Delta\rho_2(H)$ points to strong elastic response, but the data are not easily reconciled with a rigid vortex model. We find that, over a wide range of temperatures, all the pairs of curves $\Delta\rho_1(H)$ and $\Delta\rho_2(H)$ can be collapsed on a pair of scaling curves $\Delta\rho_1[H/H^*(T)]$, $\Delta\rho_2[H/H^*(T)]$, with the same scaling field $H^*(T)$. We argue that $H^*(T)$ is related to the loss of vortex rigidity due to a vortex transformation.

Key words: $Tl_2Ba_2CaCu_2O_{8+\delta}$, vortex dynamics, microwaves
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Not too close to T_c the vortex state microwave response is dominated by vortex motion. While the correct approach to the frequency dependence of vortex motion is still a debated topic, it is believed that at high enough frequencies each vortex probes only a single potential well (due to, e.g., a defect) due to the very small induced oscillations. In this case the Coffey-Clem (CC) model is effective in takeing into account vortex viscous motion, pinning and creep [1]. By lowering the frequency, vortices experience large drags from their equilibrium positions, and they can interact with each other and with several potential wells. In this case the nature and distribution of pinning centers becomes crucial, and several vortex phases can arise [2] with very different transport properties. In the single-vortex model the response is dictated by the upper critical field, which determines the weight of the viscous flux flow, and by (at least) a different characteristic field for vortex creep or pinning. By contrast, when the dynamics is dictated by a transition or a crossover between different vortex phases instead of pinning, there may be single characteristic field (in a sufficiently small region of the H, T phase diagram) describing vortex dynamics [2]. In $YBa_2Cu_3O_{7-\delta}$ [3] a single-vortex model has been applied with success to the description of the microwave response. However little is known about TBCCO.

We measured the microwave response at 47

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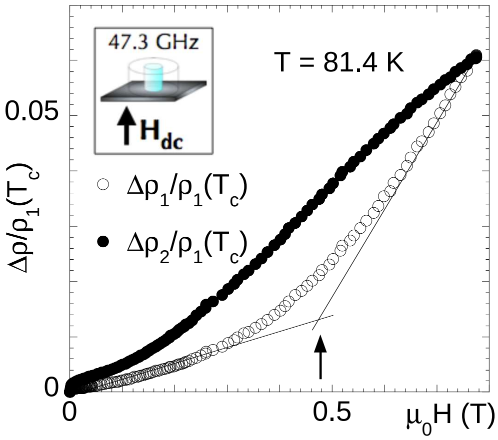

Fig. 1. $\Delta\rho_1(H)$ (open symbols) and $\Delta\rho_2(H)$ (full symbols). Arrow indicates a possible choice for $H^*(T)$. Inset: sketch of the experimental configuration. Microwave currents flow in the *ab* planes.

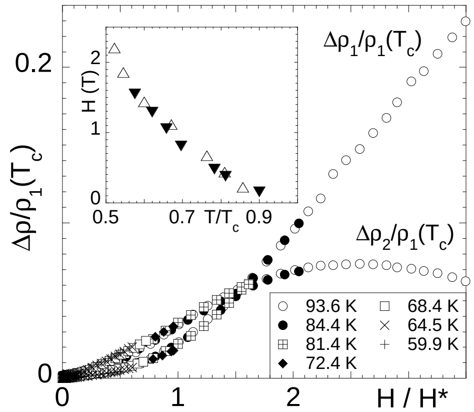

Fig. 2. Collapse of seven curves of $\Delta\rho_1$ and $\Delta\rho_2$ with $H^*(T)$. For clarity, only 10% of data is shown. Inset: $H^*(T)$ (full symbols) and melting field from [5] (scaled by 2.2, open symbols).

GHz in TBCCO thin films by means of a sapphire dielectric resonator operating in the TE_{011} mode. Changes in Q factor and resonant frequency yielded changes in the complex resistivity $\Delta\rho_1(H) + \mathrm{i}\Delta\rho_2(H)$. We checked that, in the temperature range investigated, the thin film approximation was valid. The 240 nm-thick films have been grown on 2" diameter CeO_2 buffered R-plane sapphire substrates by conventional two-step method. The resulting films show excellent (100) orientation and excellent in-plane epitaxy [4]. The full-width-half-maximum of the $\theta - 2\theta$ rocking curve is 0.4°. The film under study had $T_c \simeq 104$ K and $J_c = 0.5$ MAcm^{-2} measured inductively.

A typical measurement is reported in Fig. 1. The large imaginary part $\Delta\rho_2(H) \sim \Delta\rho_1(H)$ excludes free-flux-flow, and indicates a strong elastic vortex response. Moreover, the superlinear field dependence of $\Delta\rho_1(H)$ and $\Delta\rho_2(H)$ is not compatible with a vortex motion dominated by single-well strong pinning (Campbell regime). However, a careful analysis of the data within the periodic-potential CC model revealed that they were incompatible also with significant creep. In order to reconcile the data with the CC model, a field-dependent depinning frequency with no creep was needed, suggesting vortex collective behaviour. Due to the large amount of arbitrariness of this choice, we concentrated in the identification of some more general, albeit less model-specific, feature of the data. We found that, in agreement with the indication of collective vortex behaviour, our measurements exhibited a clear field-dependent scaling, as reported in Fig. 2: we found that $\Delta\rho_1(H,T) + \mathrm{i}\Delta\rho_2(H,T) = \Delta\rho_1[H/H^*(T)] + \mathrm{i}\Delta\rho_2[H/H^*(T)]$, with $H^*(T)$ that reproduced the temperature dependence of the vortex melting field in TBCCO single crystals [5] (inset of Fig. 2), suggesting that the dynamics was dictated by some vortex transformation. While further work is needed to clarify these issues, in this framework the large $\Delta\rho_2$ at low fields with the drop at higher fields (see Fig.2), and the temperature dependence of $H^*(T)$ would indicate a loss of vortex rigidity at some vortex transformation instead of depinning of rigid vortices.

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